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Left atrial appendage function assessment and thrombus identification☆

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ABSTRACT

Background: The diagnosis of thrombus in the left atrium in patients with persistent atrial fibrillation (AF) and may be inconsistent because of variability in thrombus morphology. In some cases it is challenging and requires unusual approach. New Doppler-derived methods might be helpful to identify such thrombi. We evaluated quantitative differences in mechanical function of the left atrial appendage (LAA) basal segments using tissue Doppler imaging (TDI)and speckle tracking echocardiography (STE) in patients with non-valvular AF with and without LAA thrombus and compared them with SR patients.

Methods: A total of 80 patients with normal left ventricular ejection fraction underwent transesophageal echocardiography (40 patients with SR and 40 patients with AF on oral anticoagulants including patients with LAA thrombus). We analyzed the basal segments of LAA including left lateral ridge (LLR) and baso-medial appendage segment (BMAS). Quantitative analysis was used to calculate peak velocity, average velocity, strain, strain rate and deformation.

Results: In patients with AF the lower LLR strain rate was the sole new STE significant parameter differentiating patients with and without LAA thrombi: $-0.9(-1.2; -0.1)s^{-1}$ vs. $-1.6(-1.9; -1.3)s^{-1}$, ($p = 0.004$). Additionally, patients in SR demonstrated significantly better peak velocity, average velocity, strain, strain rate and deformation than those with AF ($p < 0.001$).

Conclusions: LLR appeared to be an appropriate site for measuring Doppler derived parameters. It is possible that the strain rate in LLR area may be a novel parameter correlating with the presence of thrombus in patients with AF.

1. Introduction

Atrial mechanical activity plays a significant role in the disease course in many patients. Mechanical efficacy of the left atrial appendage LAA is considered an important factor in A-type natriuretic peptide (ANP) production, which stabilizes blood volume and pressure in the left atrium (LA) and may indirectly affect cardiac output [1]. The LAA is the most frequent cardiac source of thrombi in patients with AF [2–5]. Also, the LAA flow velocity has been used to assess the propensity for thrombus formation [6]. Parameters of LA mechanics were initially directly evaluated by tissue Doppler imaging (TDI) and then by speckle tracking echocardiography (STE). In recent years atrial septal and wall motion have been most frequently analyzed by transthoracic echocardiography (TTE) [7–12]. Quantitative analysis by strain imaging (SI) and strain rate imaging (SRI) most frequently includes evaluation of echocardiographic indices of left atrial filling and relaxation [13–15]. Quantification of left atrial systolic function is another important component that describes atrial mechanics [10–12,16]. In patients with AF atrial contraction is disorganized due to asynchronous atrial muscular activation [4,17,18]. The LAA as a blind-ended pouch with the thinnest walls in the heart is most susceptible to consequences of abnormal atrial contraction which may lead to thrombus formation and arterial embolism with ischemic stroke as the most severe clinical presentation [2,3,19–21]. In some cases thrombus formation in LAA is very likely but high bleeding risk requires consideration of alternative invasive treatment options [1,22–24]. In such cases the detection of LAA thrombus was based on 2D or sometimes 3D imaging. An additional clue was reduced velocity flow in the LAA. So far no STE-based outcome prediction parameters have been proposed for use in clinical practice. Unfortunately, the possibilities of direct LAA assessment are very limited, especially by echocardiography. The LAA free wall thickness ranges from 1 to 2 mm, therefore it appears extremely difficult to be visualized for mechanical evaluation with currently available technology [25]. However, basal segments of the LAA such as left lateral ridge (LLR) and baso-medial appendage segment (BMAS) near the vestibule of the mitral valve are composed of over 4 mm thick myocardial tissue, which may be suitable for TEE assessment [26,27]. This portion of the myocardium is thought to reflect to some degree LAA mechanical activity (Fig. 1). In

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patients in sinus rhythm (SR) LA contraction is delayed by about 50–60 ms from the onset of the P wave and lasts until the atrioventricular valves are closed [28–30]. The electromechanical activation of the entire left atrium in healthy subjects lasts about 20–30 ms [10,28]. In contrast, in patients with AF foci of reentrant electrical waves in the LA wall, including the LAA are found in the entire cardiac cycle between QRS complexes. An interval of 150 ms immediately before the QRS complex may be a suitable window for measuring systolic activity of the LA during AF. In some cases LAA thrombi may develop in spite of appropriate anticoagulation treatment. Therefore, medical treatment effects should be verified by TEE, mainly because the difference between the solid and sludge morphology of thrombi can be ambiguous. Moreover, the inside of the LAA is not always easily available for clot exclusion. Velocity measurements in the LAA could be helpful but it is only an indirect parameter and requires additional methods to confirm the diagnosis. Another parameter of thrombus detection would be of crucial importance.

2. Methods

2.1. Patients

A total of 80 patients aged from 18 to 80 years were included (40 with SR and 40 with AF for at least 3 months). The exclusion criteria were as follows: valvular heart defect (any form), rhythm other than SR or AF, prosthetic valve, the presence of shunt except patent foramen ovale, pulmonary arterial hypertension, any cardiac device implanted, all classes of heart failure and EF < 55%, arterial hypertension, atrioventricular conduction abnormalities, sinoatrial blocks and esophageal pouches or other abnormalities that make TEE difficult. ECG recording prior to TEE was performed in each patient to confirm the rhythm eligible for analysis. All patients had their height and weight measured to calculate body surface area (BSA) and body mass index (BMI). Anticoagulants were administered with INR maintained over 2.0 in patients treated with vitamin K antagonist or with novel oral anticoagulant dose titrated according to the glomerular filtration rate, respectively. This group included eight patients meeting the inclusion criteria and having LAA thrombi despite appropriate anticoagulation therapy. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki Informed consent was obtained from all patients. The study was approved by the Bioethics Committee of the Local Chamber of Physicians.

2.2. Transthoracic echocardiography

All patients underwent TTE for confirmation of study inclusion criteria using the General Electric Vivid E9 device (version 112; upgrade BT12) and a sector array M5S (2.5–3.5 MHz) transducer. The following parameters were analyzed: LA diameter, LA area, left atrial volume index (LAVI) and left ventricular ejection fraction (LVEF). The size of left atrial cavity was measured at end diastole in the parasternal long axis view (PLAX) and then indexed to the patient's BSA. LA area was measured in the apical four chamber and the apical two chamber views at end diastole and then LA volume was calculated. The left ventricular ejection fraction was calculated with the biplane Simpson's method using the apical four chamber and the apical two chamber views.

2.3. Transesophageal echocardiography

TEE was performed using the same device and a TEE omniplane 6Tc (6–8 MHz) transducer. LAA images were obtained in the long axis view at the level including the appendage itself, LA cavity, left upper pulmonary vein draining into the LA, mitral leaflets and basal segments of the left ventricle. Moreover, thickness and length of LLR in the long axis of LAA were measured. Flow velocity in the LAA was measured. The view was obtained by positioning the transducer in a range of 50–110°. The LAA was also inspected for the presence of thrombi. HR was recorded in all patients.

2.4. Tissue Doppler imaging

TDI was performed at a frame rate of over 100 frames per second (fps). During a TEE procedure the patient's ECG was recorded. TDI echocardiograms included potential sites for STE analysis within the region of interest and at least three QRS complexes. Measurements were made within LLR near its top (area A) and near its bottom (area B). BMAS was the third point of measurement (area C) (Fig. 2). In order to acquire images at fps > 100 in some cases it was not possible to visualize simultaneously all measurement areas, i.e. A, B and C. For this reason the region of interest (ROI) showing A and B and separately the ROI that included C were selected for analysis. The peak atrial velocity in the middle of LLR was also measured using pulse-wave TDI (PW-TDI) (Fig. 3). This measurement served as the basis for calculating TDI-derived peak velocities. The beam-to-flow deviation in PW-TDI was established. Peak velocities in patients with SR and AF were measured in the same beam positions. In patients with SR and AF peak positive LLR values were measured at 150 ms before the QRS complex. In AF patients measurements were performed when the duration between QRS complexes exceeded 800–900 ms.

2.5. Post-processing analysis

Off-line analysis was performed with the Q-Analysis software (General Electric EchoPac workstation, version 112; upgrade BT12). The TDI recording at 150 ms before the QRS complex was selected for analysis of the systolic phase in all segments. In TEE in the view enabling visualization of the LAA in the longitudinal axis the TDI sector width was

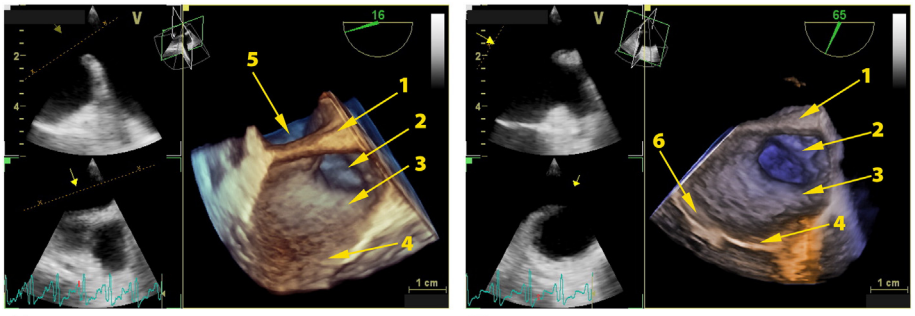

Fig. 1. Panel A. TEE: 3D superior view into left atrial cavity and LAA. 1-left lateral ridge, 2-left atrium appendage, 3- baso-medial appendage segment, 4-mitral posterior leaflet, 5-left common pulmonary veins. Panel B. TEE: 3D anterior view into left atrial cavity and LAA. 1-left lateral ridge, 2-left atrium appendage, 3-baso-medial appendage segment, 4-mitral posterior leaflet, 6-mitral anterior leaflet.